

Ticosonde Observations of Waves in the Tropical Tropopause Layer, 2004-2006

Henry Selkirk^{1,2}, Holger Vömel³, Leonhard Pfister², Jessica Valverde⁴, Werner Stolz⁵, Jorge Andrés Díaz⁶, Walter Fernandez⁷, Jorge Amador⁷, Eladio Zárate⁸, Randy May⁹, Grace S. Peng¹⁰, Jimena Lopez^{1,2}, Marion Legg^{1,2}, Juan Valdés⁴, Victor Hernández and Fellow IMN Radiosondistas⁵, Kristel Heinrich and Fellow UCR Students⁷, and Jose Pablo Sibaja and Fellow UNA Students⁴

¹Bay Area Environmental Research Institute ²NASA-Ames Research Center ³CIRES/University of Colorado ⁴Escuela de Química, Universidad Nacional (UNA)
⁵Instituto Meteorológico Nacional (IMN) ⁶Centro Nacional de Alta Tecnología (CENAT) ⁷Escuela de Física, Universidad de Costa Rica (UCR)
⁸Comité Regional de Recursos Hidráulicos (CRRH) ⁹MayComm Instruments, LLC ¹⁰The Aerospace Corporation

Introduction

The temporal variability of the deep tropical upper troposphere and lower stratosphere, or UT/LS, during the northern summer season is, like the troposphere below, dominated by wave disturbances at synoptic and shorter time scales. This is certainly true in the ITCZ of the Caribbean/Central American region. Particularly prominent in Figure 1 at right is a westward-propagating diurnal variation in cold cloudiness which is modulated on timescales of several days and longer by a complex of eastward moving disturbances. Some of these disturbances propagate vertically through the Tropical Tropopause Layer (TTL) and into the stratosphere above where quasi-biennial variations of the zonal wind profile will affect the rate and depth of the energy propagation.

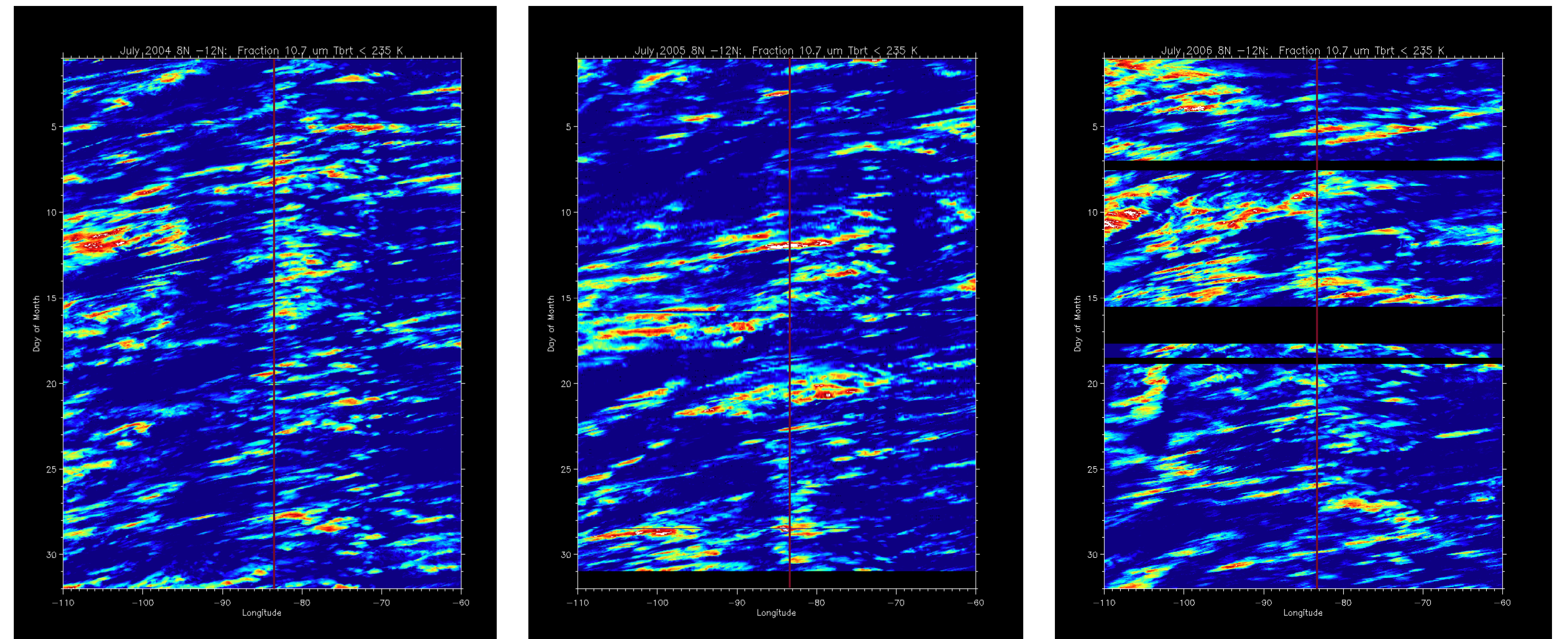


Fig. 1: Hovmöller diagrams for the month of July in 2004, 2005 and 2006 of fractional coverage of GOES-12 brightness temperatures below 235 K between 8 and 12°N over the longitude band 60°-110°W. The heavy red line shows the longitudinal location of Juan Santamaría International Airport, Alajuela, Costa Rica.

Disturbances propagating through the TTL and into the stratosphere

Figure 5 shows very regular downward phase propagation through the lower stratosphere and into the TTL, indicative of upward propagation of wave disturbances. These are likely related to integrated forcing by convective activity over the region (see Figure 1 above.) The dominant frequency is 4-5 days, and there are likely to be both Kelvin and mixed-Rossby gravity (Yanai) wave contributions.

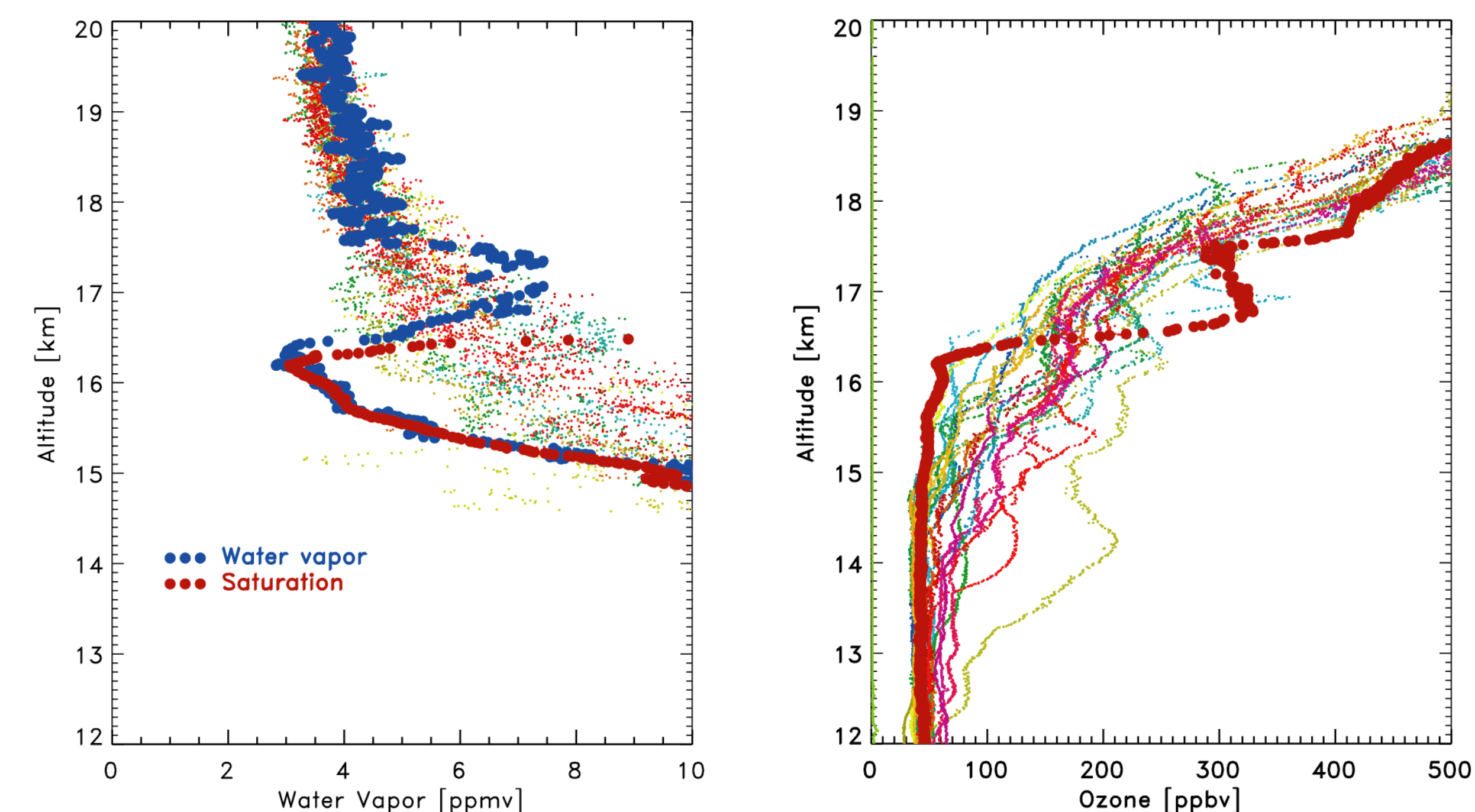


Fig. 2: The entire set of 24 profiles of water vapor mixing ratio and saturation mixing ratio (left) and ozone measured during the Ticosonde/Aura-TCSP sounding program in July 2005 by a balloon payload with the University of Colorado cryogenic frostpoint hygrometer (CFH) and an ECC ozonesonde. The profiles in bold were taken close to midday (18UT) on July 19.

Wave-induced cooling at the tropopause and the Quasi-Biennial Oscillation

The extreme cooling and concomitant dehydration at the tropopause to roughly 3 ppmv on July 19, and similar event on July 11, shown in Figure 2 came about through the superposition of wave-induced cold anomalies. Figure 3 shows that Ticosonde/Aura-TCSP soundings in 2005 occurred during a strong easterly period of the Quasi-Biennial Oscillation while the Ticosonde/NAME measurements in 2004 took place in during weak easterly phase. Ticosonde/Veranillo soundings in 2006 took place as the easterlies were beginning to descend through 30 km.

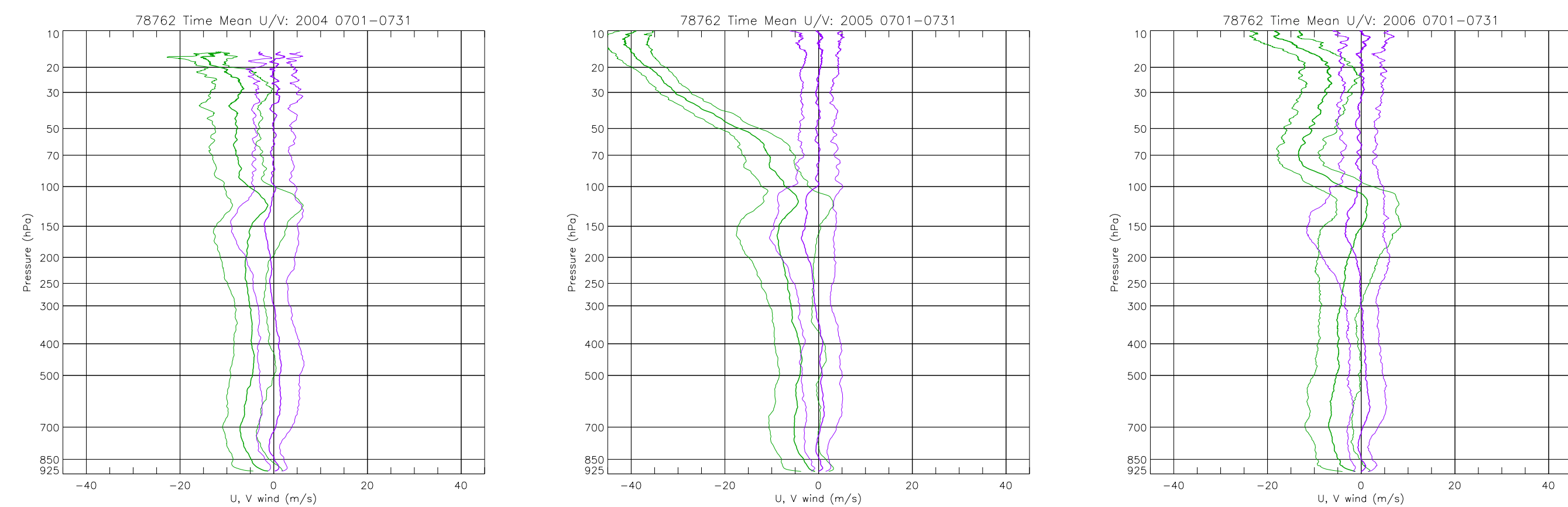


Fig. 3: Ticosonde mean winds for (from left) the month of July in 2004, 2005, and 2006. Zonal wind in green, meridional wind in violet; outer lines define plus/minus 1 standard deviation.

Figure 4 plots the mean soundings for the three Ticosonde northern summer campaigns. While it is noticeably cooler at 50 mb during the strong easterly period in 2005, the temperature range of the coldpoints in 2004 is restricted relative to the other two years. We suggest that the cause of the greater amplitudes of the coldpoint variations in the latter two years is related to the stronger shear above the tropopause.

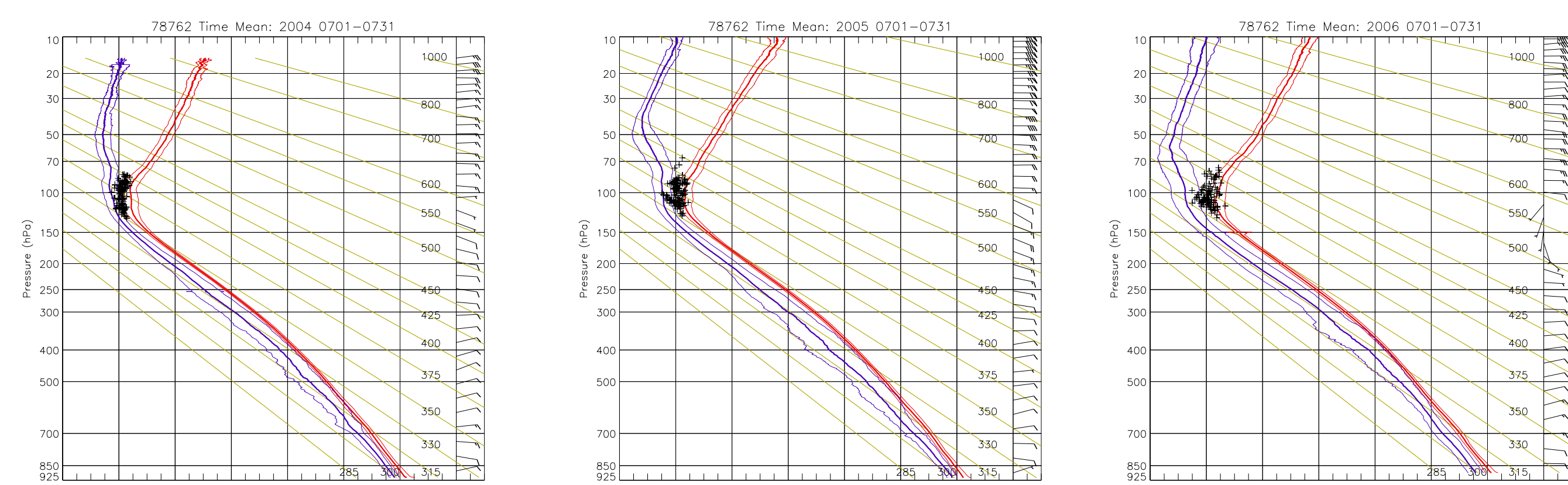


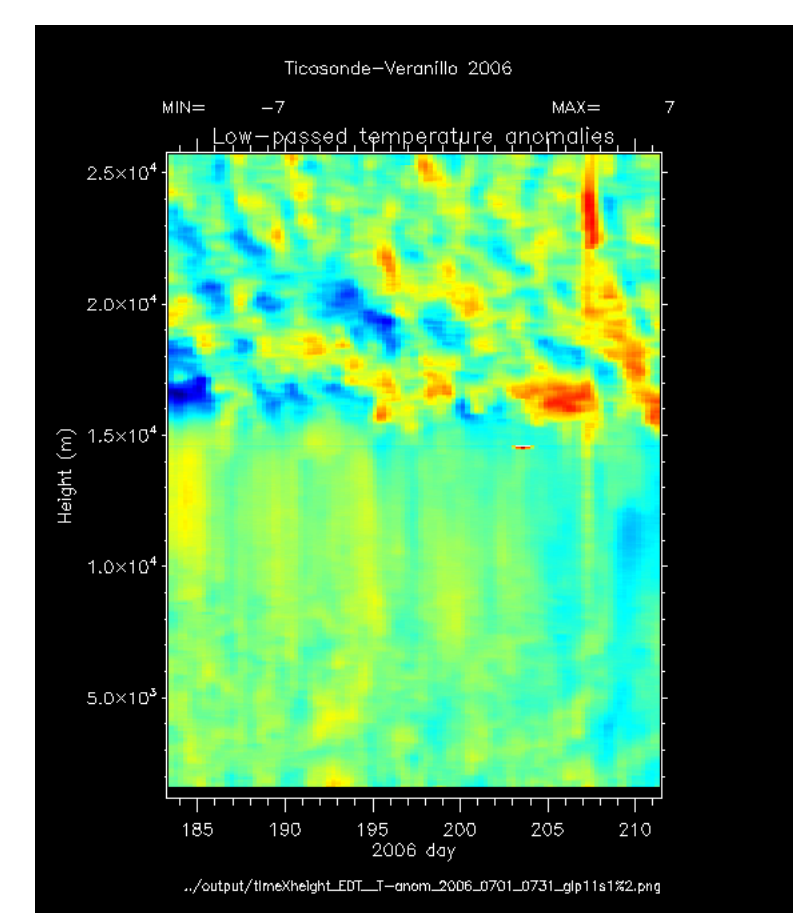
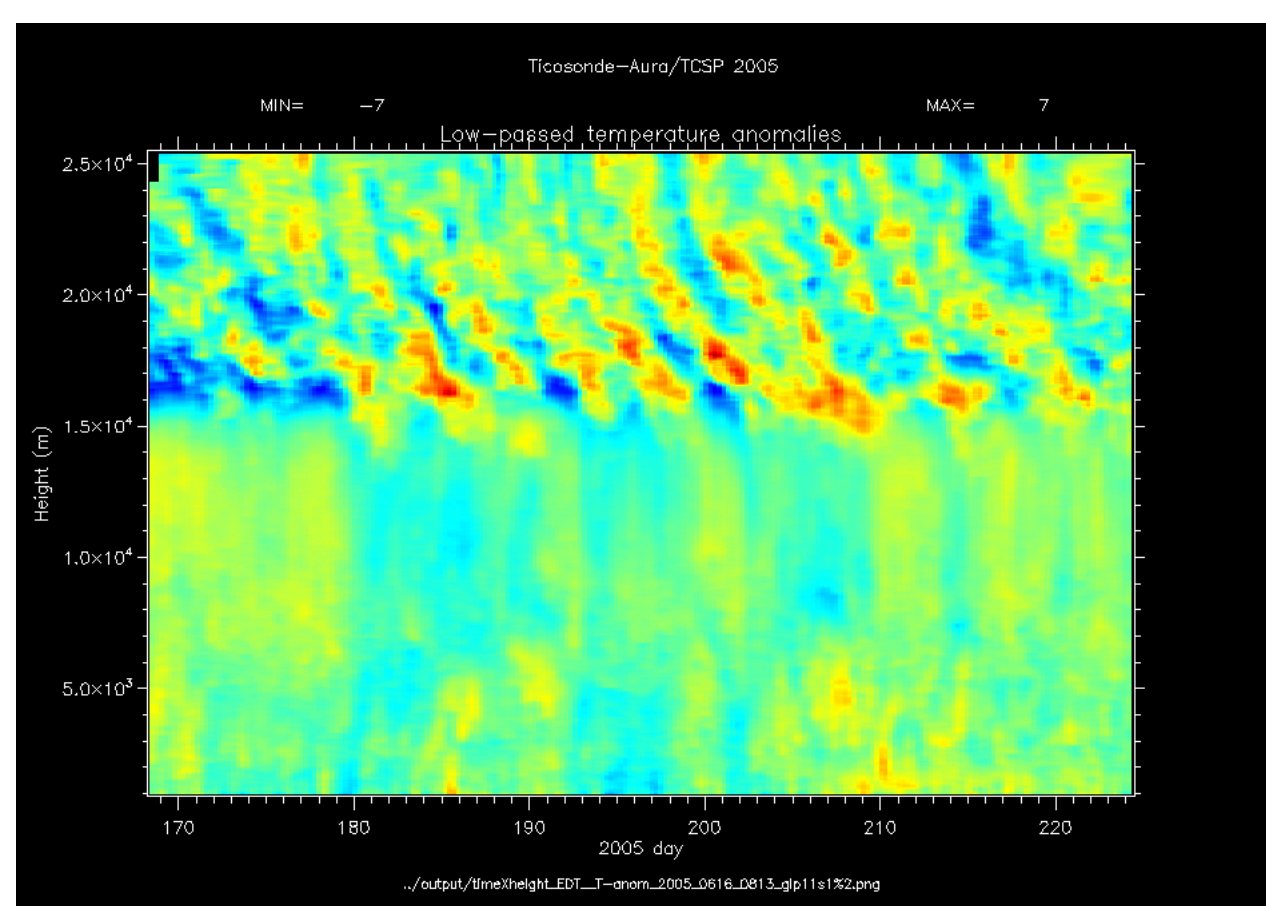
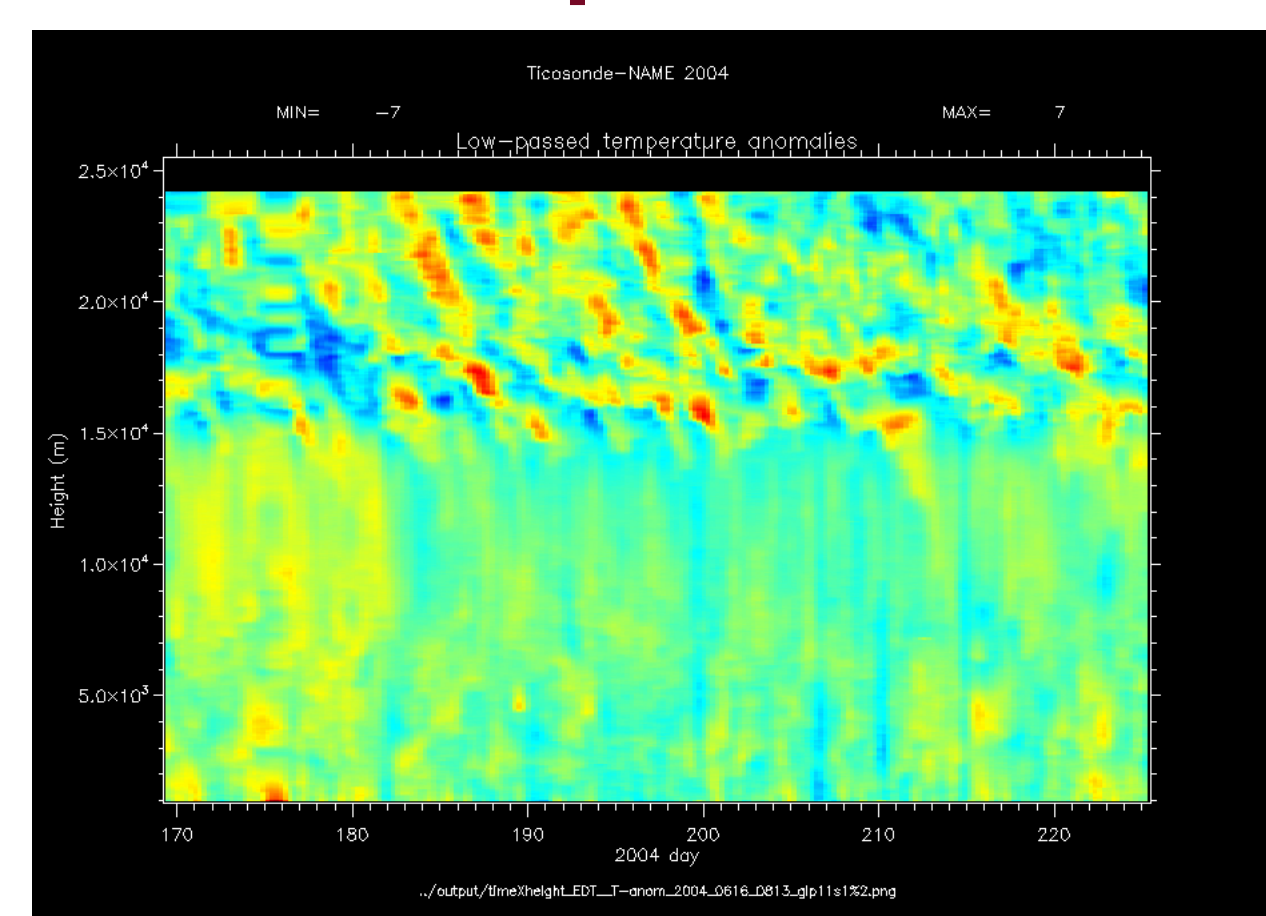
Fig. 4: As in Fig. 3 but for profiles of temperature and dewpoint. Winds plotted at right with barbs in knots. Individual coldpoint tropopauses are indicated by the black crosses. 2004 data is all Vaisala RS90-AG, 2005 all RS92-SGP and 2006 is roughly 2/3 RS92 and the rest RS80.

2004

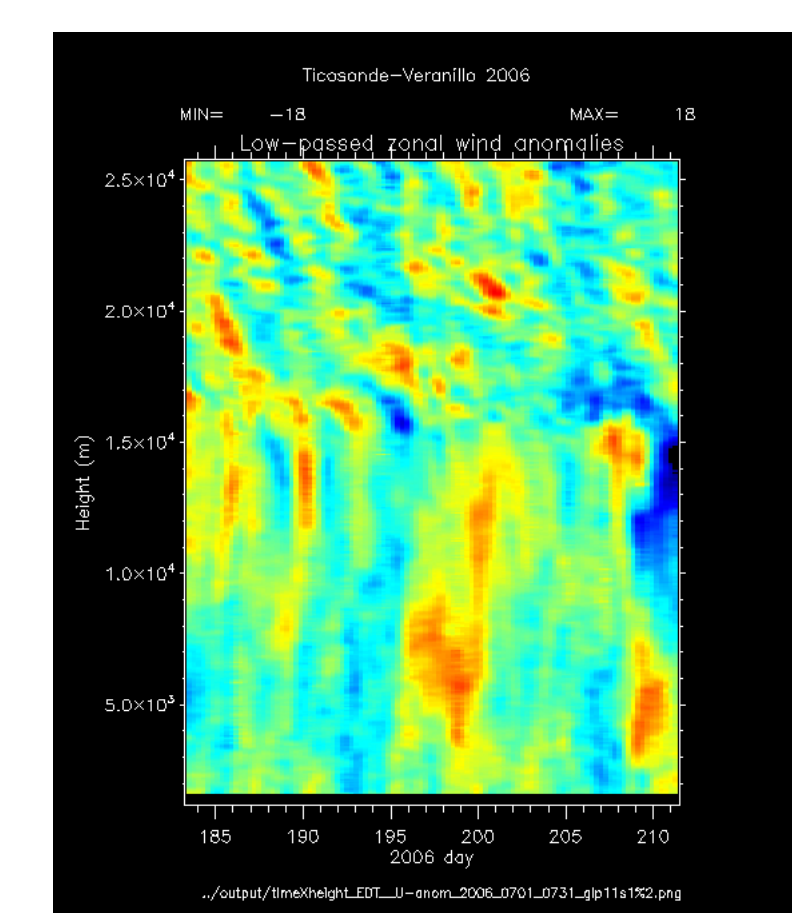
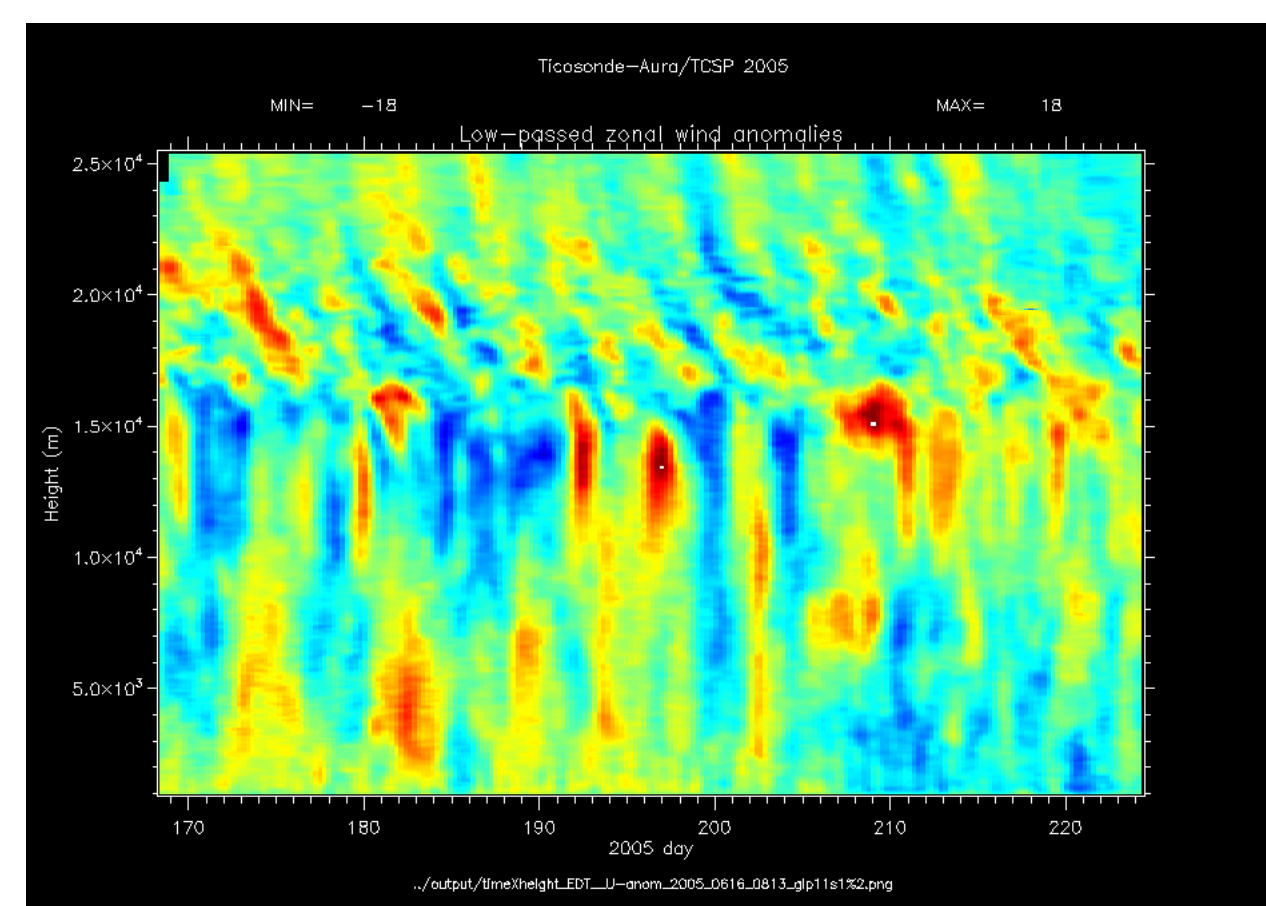
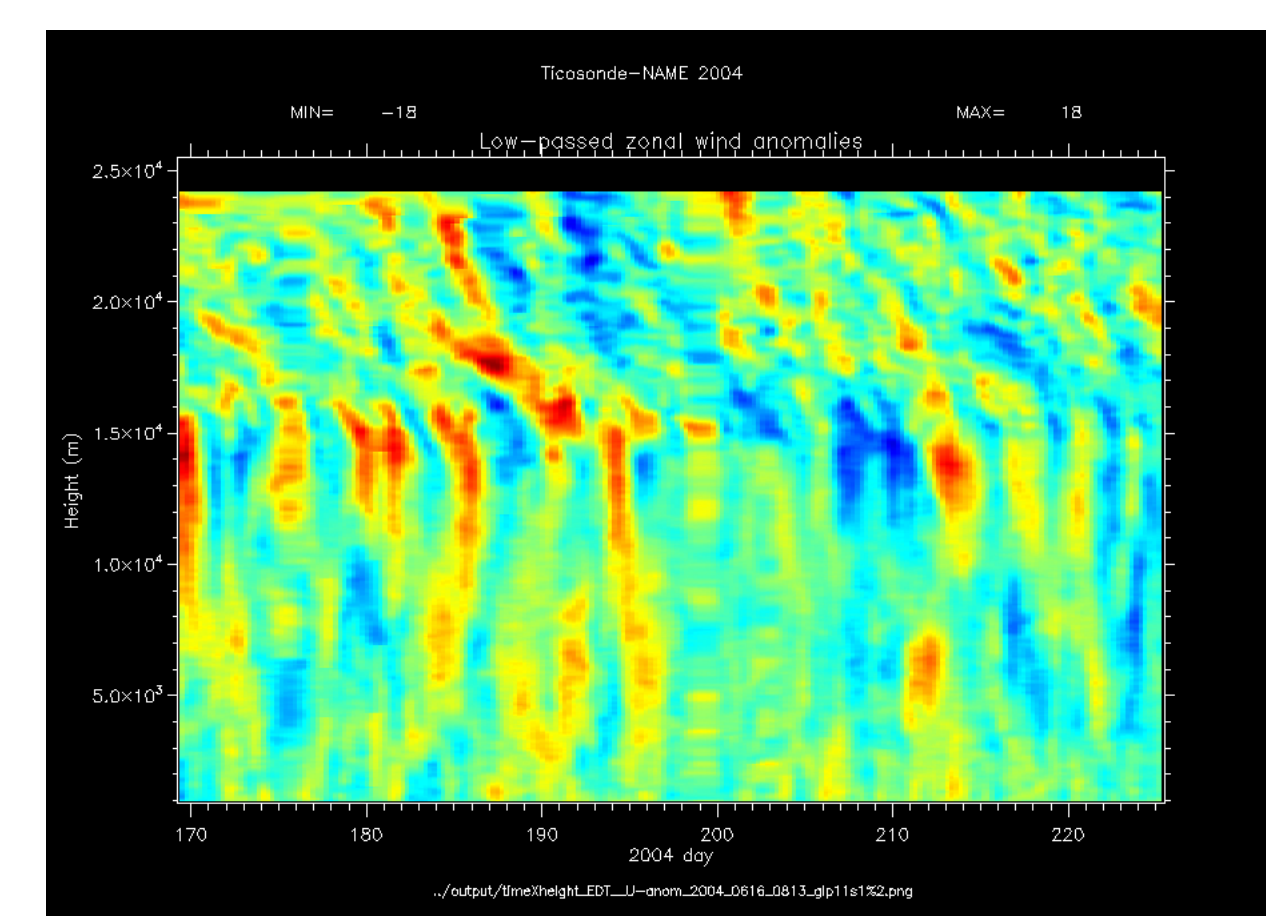
2005

2006

Temperature



Zonal Wind



Meridional Wind

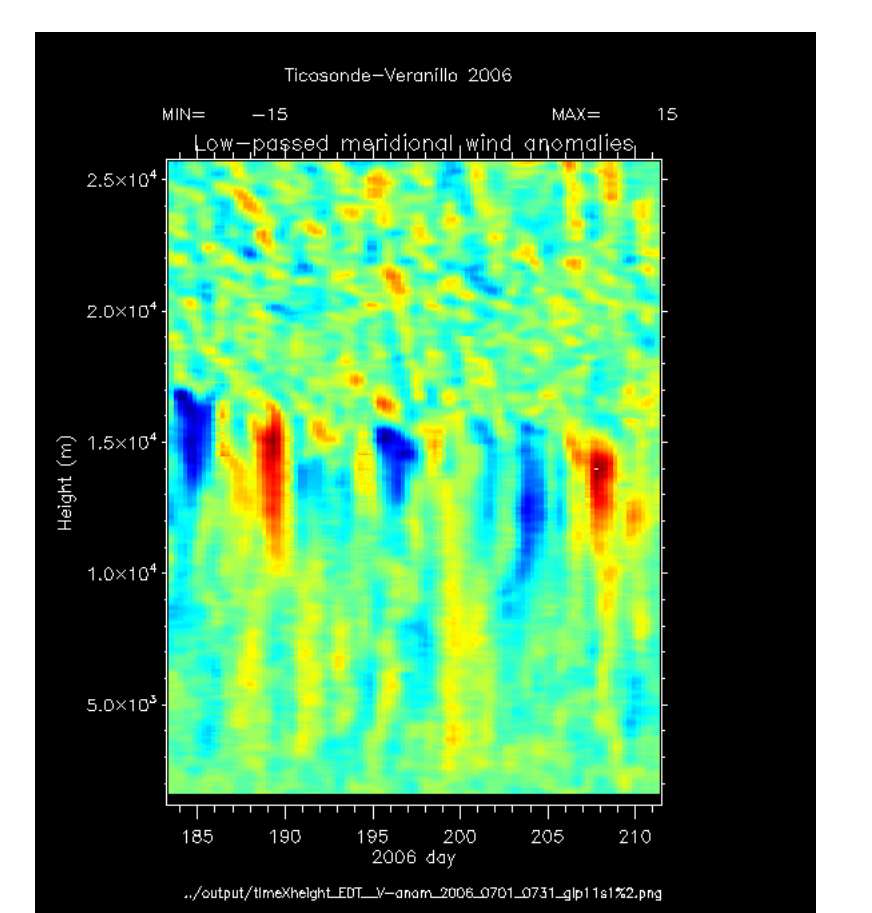
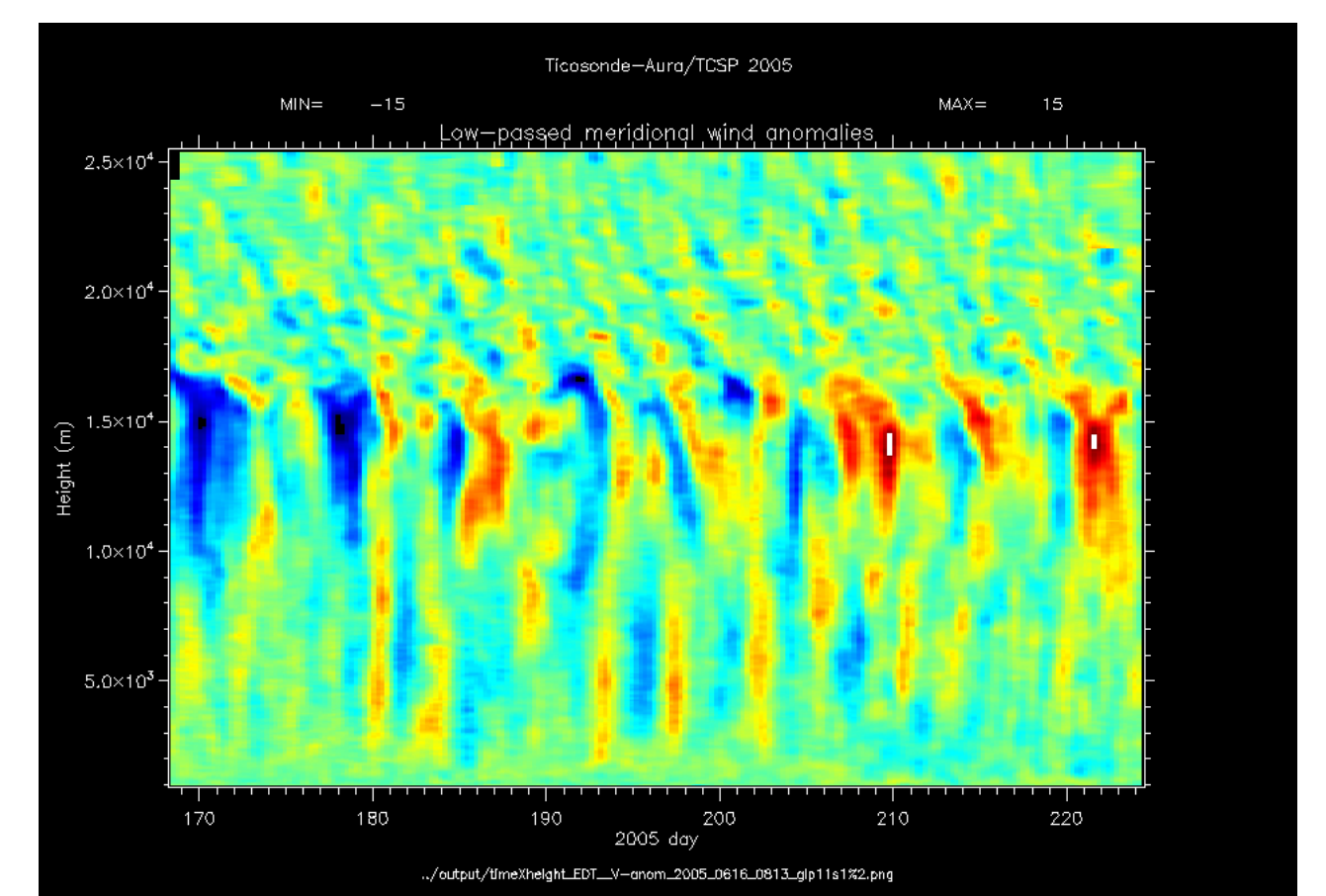
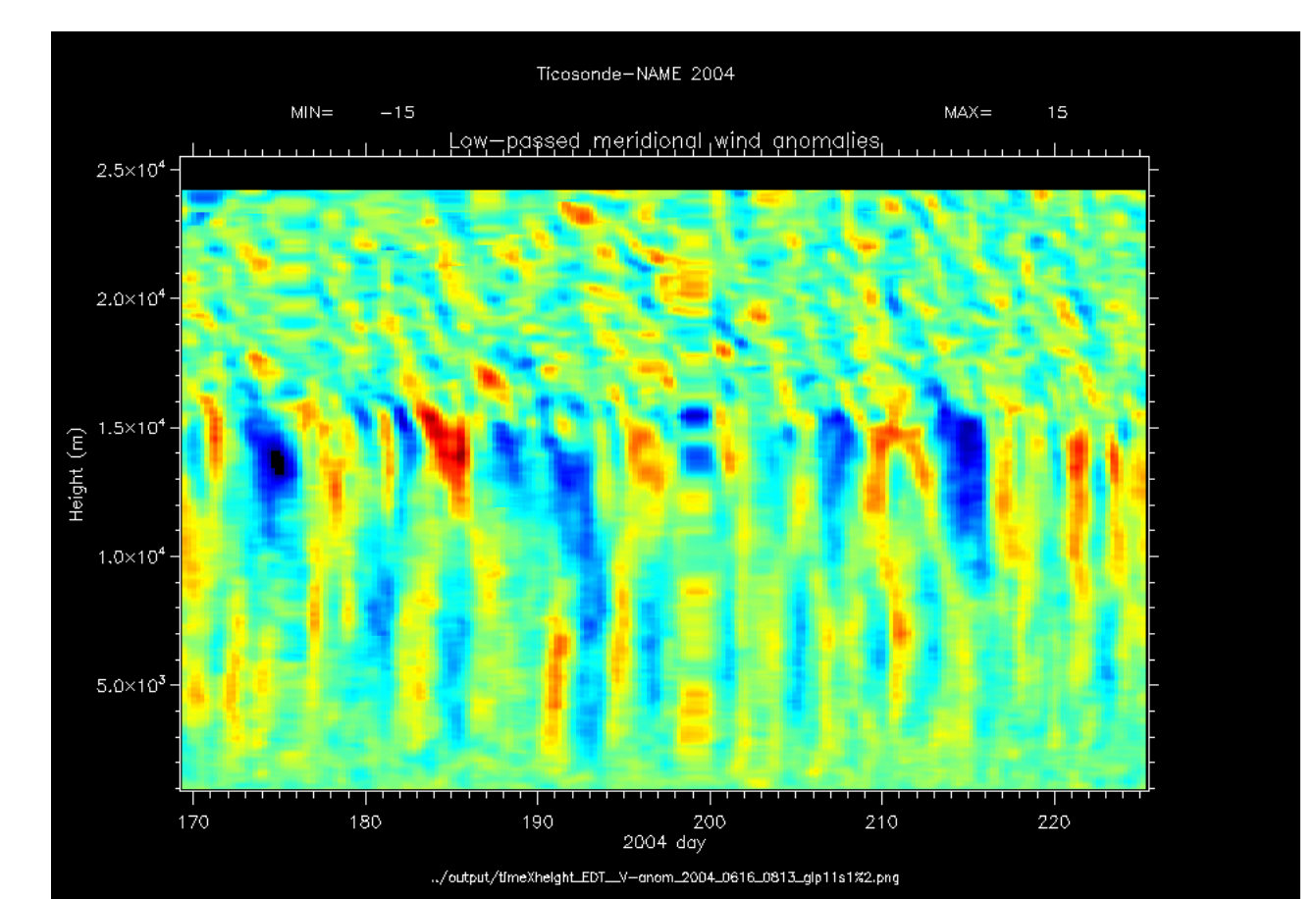


Fig. 5: Time-height cross-sections of anomalies of T, U and V between the surface and 25 km for the two-month periods of 6/16-8/31 in 2004 and 2005 and the month of July in 2006.

Interannual variability of upward wave propagation and dehydration at the tropopause

Theory suggests that the upward group velocity of wave disturbances could be inhibited for at least some waves by strong easterly shear in the lower stratosphere, with one result being a buildup of wave energy near the tropopause. The time-height cross-sections of T, U and V anomalies in Figure 5 lend support to this notion, as they indicate that there was more propagation of wave energy in 2004 into the middle stratosphere compared to 2005 and 2006. The greater variability of temperatures in the latter two years near the tropopause, and the potential for dehydration in extreme cold events, occurred during the presence of significant easterly shear in the lowermost stratosphere. In this way the QBO may indirectly influence the dehydration of the stratosphere.